Cyclotron Resonance of Composite Fermions:Quantum Hall Effect.

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We have examined the claim made by Kukushkin et al that they have observed the cyclotron resonance of composite fermions. We find that the claim made is false and there is no justification for making false reports. The microwave absorption in cyclotron levels is obtained and it is claimed that CF has been seen. Since "even flux quanta attachment to one electron" has not been seen, we find that Kukushkin's claim to have seen the CF is false. Since the attachment of the flux quanta to electrons can be an important discovery, Kukushkin et al have made the claim of seeing the CF without actually identifying them. The data can be interpretted without attaching flux quanta to the electrons.

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1. Introduction.

First of all, we should define CF. By CF we mean composite fermions (CF) which are magnetic flux quanta attached to the electron. Even number of flux quanta, such as 2, are attached to one electron to make a CF. The effective field at the CF is given by,

$$B^* = B - 2n_o\phi_o \ , \tag{1}$$

where B is the exernal magnetic field, n_s is the electron concentration per unit area and ϕ_o is the unit flux $\phi_o = hc/e$, It is found by Jain [1-6] that attaching two flux quanta to one electron produces an effective charge of 1/3. Thus we have three properties to identify a CF. (1) Attachment of two flux quanta to an electron, (2) effective field is B* and (3) the quasi particle charge is 1/3 for the attachment of two flux to one electron.

We will now examine whether these properties are found by Kukushkin et al[7] or they have made a mistaken report. From this study we find that the identification of CF in the experimental data by Kukushkin et al is incorrect.

2. The experimental measurement.

Recently, Kukushkin et al[7] have measured the microwave absorption as a function of magnetic field. They find that absorption lines at the cyclotron frequency are symmetrically situated from the centre at ν= 1/2 which occurs at a field of about 9 T. The frequency as a function of field is a linear function. The effective field is identified by the expression (1). Substituting B* = 0 at ν= 1/2, we find,

$$B = 2n_s\phi_o \tag{2}$$

We take n_s = 1.09 $\times 10^{11}$ and ϕ_o = 4.13$\times 10^{-7}$ Gauss cm^2 so that the field B is found to be about 9 T. Alternatively, we take the field, at which ν= 1/2 occurs and the value of ϕ_o to calculate the electron concentration, n_s. The field B as a function of n_s is approximately linear. However, upon examination of a few fundamental properties, it becomes clear that not everything is fine and there is something not quite correct.

I. Near the B*=0, the plot of microwave frequency as a function of the effective field B* is linear. Since $B = 9T$, the plot of microwave frequency versus field, B*, extends from negative to positive values. For $B < 2n_s\phi_o$, the value of B^* is negative and for B$^* > 2n_s\phi_o$, it is positive. The graph appears symmetric near B* = 0. When we look at the values of the large plateaus, the right hand side which is the positive B^* side, has a plateau at $\nu = 3/7$ whereas the left-hand side has 3/5. Basically it means that at the plateaus, the left-hand side is not equivalent to the right-hand side. If there is a time reversal invariance in the system, the right-hand side should be the same as the left hand side, like mirror images with mirror at $B^* = 0$. On the other hand 3/5 on left and 3/7 on the right do not make the picture symmetric and the time reversal invariance is not obeyed by the experimental data. Therefore, the data has not been identified correctly. Hence, eq.(1) which introduces two fields, one B and the other B^* is not correct.When we pass a current in a coil, a field is produced. Reversing the direction of the current reverses the field. The expression (1) is obviously not having this simple property and hence we can say that the field discription(1) is not correct.

II. We have shown[8] elsewhere that the usual Biot and Savarts law is not obeyed by the expression (1). According to which the current fully determines the field so there is no question of attaching the flux quanta to electrons. The flux quantization is determined by an expression of the type,

$$B.area = \phi_o \tag{3}$$

but the expression (1) is not in agreement with the flux quantization. Therefore the idea of flux attachment to the electron is not correct. In any case, the data is asymmetric near $\nu = 1/2$ whereas the formula (2) is symmetric. Therefore, Kukushkin et al have not varified the expression (1).

III. According to the original papers [1-2] on the composite fermions the attachment of two flux quanta to one electron produces the fractional charge of 1/3 but the experiment of Kukushkin et al has used the value of 1/2. Therefore,the experimental data does not agree with the CF value. The application of the two flux attachent to $\nu = 1/2$ is not justified and hence the observed resonance is not the result of cyctotron resonance of CFs. The application of the two flux attachment to $\nu = 1/2$ is not justified and hence the observed resonance is not the result of the cyclotron resonance of CFs. Different bands belong to different energies so that one obtains different effective mass for different frequencies, $\omega = eB/m^*$. Therefore, it is perfectly justified to use different masses in different bands but the effective charge identification by Kukushkin et al is mistaken. They have mistaken 1/2 for 1/3. Therefore, it is clear that the symmetry of CF given by (1) is not the same as in the experimental data. The effective charge in the CF is 1/3 but it is 1/2 in the data. There is no evidence of attachment of two flux quanta to one electron in the data. Therefore, the theory of CF is not applicable to the experimental data of Kukushkin et al and they have made incorrect identification of data with CF. In short, all the efforts made to identify the CF in the experimental data have failed. The relation which determines the effective field by attaching two flux quanta to one electron has to be abolished. This means that fluxes are not attached to the electrons. Therefore, even number of fluxes, such as two, are not attached to the electrons. When we examine the experimental data, there is no feature which can be identified with "even number" of flux quanta attachment.

3. Correct Theory.

We show below that the use of our theory [9-13] solves the problem correctly. The quantum Hall effect is explained by suggesting that in a large field, the electron acquires large angular momentum and the effective charge is determined from the modifications of the Bohr magneton. The charge is coupled to the spin and there are two series which determine the effective charge. One series is obtained with positive sign of the spin and the other with negative sign as in $j = l \pm s$. One of the series is $l/(2l+1)$ and the other is $l + 1/(2l+1)$. When we substitute, l=2, the two series give 2/5 and 3/5 and these are the particle-hole Kramers conjugate states. For l=3, the fractions are 3/7 and 4/7 and these are also the Kramers conjugate states. The values of 3/5 and 3/7 as predicted by us are clearly seen in the experimental data of ref.7. All of the values which we tabulated [9] theoretically in 1986 are the same as those given by the experimentally measured values of Fig.18 of Störmer[14]. Therefore, we regard our theory as correct. We have

made considerable study of the data and find that all of the experimental data found in the Phys. Rev. Letters agrees with our calculations.

In recent years, large values of the effective fractional charges have been obtained by spectroscopic methods. In one case, the sample is illuminated with a red light and then this light is switch off and subsequently the resistivity is recorded[15]. In this case, the resolution is considerably improved so that the fractions like 11/2 and 16/2 become visible. Such large values are not due to attachment of flux quanta to an electron. There is no mechanism of gluing the flux quanta with electrons and there is no experimental evidence of flux quanta coming off the electrons. This is a bit too far fetched idea and hence can be safely discarded. Willet et al [16] also find that as higher Landau levels are traversed, the validity of the CF picture is questionable. However, they report that there is a filled Fermi sea of CFs at 5/2. It turns out that at 5/2, there may be a Fermi sea but it does not prove that flux quanta are attached to electrons. In any case, there is no evidence of even number of flux quanta attaching to electrons. Auslaender et al [17] have performed the experiments with parallel wires and found that flux is quantized in units of hc/e but there is no evidence of attachment of flux quanta to electrons. Therefore, the correct interpretation involves flux quantization and not flux attachment.

4. Conclusions.

We have shown clearly that fluxex are not attached to the electrons and there is no need of composite fermions what so ever. The claim made by Kukushkin et al to have seen the CFs is completely incorrect and unjustified. Therefore, we observe that (a) the expression (1) for B* is incorrect because it does not obey the time reversal invariance and it does not quantize the flux correctly. (b) The fractional charge which the attachment of two fluxex to one electron produces is 1/3 in the CF whereas it is 1/2 in the experiment[7]. (c) There is no experimental evidence to support the suggestion of attachment of “even number” of flux quanta to an electron and the claim made by the experimentalists is incorrect.

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